

Measurements of Wave-Lengths

OF THE

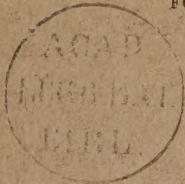
SPARK SPECTRA OF CHROMIUM AND CALCIUM; ALSO OF
THE ARC SPECTRA OF CERIUM AND THORIUM;
TOGETHER WITH A STUDY OF THE POSSIBLE
INFLUENCE OF VARIATIONS OF CURRENT,
CAPACITY, ETC., IN THE SPARK CIRCUIT

BY

FRANK LAWRENCE COOPER

DISSERTATION

SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES OF THE JOHNS HOP-
KINS UNIVERSITY IN CONFORMITY WITH THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY



BALTIMORE

1909

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MEASUREMENTS OF WAVE-LENGTHS OF THE SPARK SPECTRA OF CHROMIUM AND CALCIUM; ALSO OF THE ARC SPECTRA OF CERIUM AND THORIUM; TOGETHER WITH A STUDY OF THE POSSIBLE INFLUENCE OF VARIATIONS OF CURRENT, CAPACITY, ETC., IN THE SPARK CIRCUIT¹

By FRANK LAWRENCE COOPER

I. MEASUREMENT OF SPARK SPECTRA

INTRODUCTION

The spark spectra of chromium and calcium are of considerable interest since the solar spectrum contains a great number of lines which correspond to those found in the spectra of these metals.

Wave-lengths of the spark spectra of chromium and calcium have been made by Huggins, Thalén, Kirchhoff, Hartley, Adeney, Lockyer, and Liveing and Dewar;² but the most recent determinations are those of Exner and Haschek,³ being a part of their great work on the ultra-violet spark spectra of the elements.

The last observers made all their measurements from plates taken in the first-order spectrum of a 15-foot concave grating. Their method of measurement, which was not entirely free from objections, was to project an enlarged image of their negatives upon a screen

¹ Dissertation submitted to the Board of University Studies of the Johns Hopkins University in conformity with the requirements for the degree of Doctor of Philosophy, June, 1907.

² Watts, *Index of Spectra*.

³ *Sitz. der Kais. Akad. der Wiss. in Wien*, 1897, and following years.

where it fell upon a scale of 5 mm divisions, from which they read off the wave-lengths. Considering these two facts it is reasonable to expect greater accuracy from measurements made with a carefully constructed dividing engine and upon plates taken in the second-order spectrum of a 21-foot concave grating, as was the case with the wave-lengths between λ 2900 and λ 5000 given in the following tables. For these reasons it was thought desirable to make a more careful study of the spectra of these metals.

THE PRESENT MEASUREMENTS: APPARATUS

The grating employed in this work was, as mentioned above, a 21½-foot concave Rowland grating with 20,000 lines to the inch, mounted as described by Professor Ames in the *Philosophical Magazine* (5), 27, 369, 1889, and being in all respects the same instrument used by Professor Rowland in his work on the solar spectrum. For the purpose of comparison of spectra, the camera carries a shutter consisting of a long brass plate, capable of revolution around a horizontal axis and having, throughout its length, a horizontal opening of width equal to the thickness of the plate; so that when the shutter is in a vertical position, the photographic plate is exposed along a strip extending over the whole length of the plate and over a width equal to the thickness of the shutter. When the shutter is turned horizontally, the central strip is covered and the remainder of the plate above and below the strip is exposed. The camera-box was fixed rigidly upon the track by means of wedges placed under the wheels carrying the camera-box.

The spark was produced by a 110-volt alternating current of about 30 amperes with a frequency of 60 cycles per second. After being stepped up to about 1000 volts, it was passed through a transformer known as the "Rowland coil," which raised the potential sufficiently to produce a spark about two centimeters in length. The "Rowland coil" consists of a primary of 8 layers of 150 turns each of No. 12 insulated wire, and a secondary of 98 layers of 164 turns each of No. 25 copper wire. The spark terminals were pieces of the metal to be studied, turned down at the spark ends to the shape of a blunt lead-pencil point. The points would wear down slightly during a long exposure, but care was taken to turn them down to the proper shape

before each and every exposure. They were given this shape so that the spark would keep on the slit throughout an exposure.

The arc for the comparison spectrum was produced by a 110-volt direct current of about 10 amperes.

Both the arc and spark lamps were placed (the arc nearer the slit) upon a platform which was movable upon two knife-edges in a direction parallel to a line drawn through the centers of the slit and grating respectively. Stops were placed before and behind the platform at such a distance from it, that when it was against one of them the arc was in focus, and when it was against the other the spark was in focus; that is, in both cases the source of light was in precisely the same place at a distance of 130 centimeters from the slit.

The light was focused upon the slit by means of a quartz condensing lens which was never disturbed during the exposure on any one given plate, so that all exposures would have the grating illuminated as near as possible the same. The spark-gap was usually 8 or 9 mm in length and its image on the slit about 6 mm.

In the secondary circuit, there were several condensers consisting of plates of copper foil and glass surrounded with transformer oil. The capacity could be varied from 0.0036 to 0.245 microfarad.

The plates used were Seed's Orthochromatic, Seed's No. 27, Cramer's Isochromatic, and Wrattan & Wainwright's Panchromatic, all cut $1\frac{1}{4}$ by 19 inches, and were developed with a hydrochinone solution according to Jewell's formula.¹ All measurements on plates were made with the dividing engine which is fully described by Humphreys in the *Astrophysical Journal*, 6, 180, 1897, and also by the method described at the same place.

METHOD OF EXPOSURE

As stated before, the arc and spark lamps were on a movable platform. The spark spectrum was usually taken first; the shutter turned, and then the platform, which was independent of the mounting of the grating, was carefully slipped back on the knife-edges, thus placing the arc in exactly the position previously occupied by the spark.

¹ *Astrophysical Journal*, 11, 240, 1900.

LINES USED AS STANDARDS

The standards used were iron lines whose wave-lengths have recently been determined by Fabry and Perot, that is, for that part of the spectrum extending from λ 2373.737 to λ 6494.994, which were the limits of Fabry and Perot's measurements. For the shorter wave-lengths the standards used were lines whose wave-lengths have been redetermined by Mr. L. E. Jewell, basing his measurements upon the original wave-lengths of Professor Rowland.

CORRECTIONS

A calibration curve was drawn for each and every plate with wave-lengths as abscissae and the difference between readings and the arc standards as ordinates. From these curves the corrections for intermediate lines were read off.

TABLES OF WAVE-LENGTHS

In the tables, *r* means that the line is reversed, *d* that it is doubly reversed, and *tr* that it is reversed three times. *R* and *V* indicate that the line shades off on the red or violet side respectively. *n* means that the line is nebulous; and *br* that it is broad.

In making the estimates of relative intensities between the arc and spark lines, the iron line 4045.969 was taken as standard. This intensity is marked 30 and corresponds approximately to Kayser's mark 10.

CALCIUM

WAVE-LENGTH	INTENSITY		WAVE-LENGTH	INTENSITY	
	Spark	Arc		Spark	Arc
2208.82 <i>br</i>	o		4526.976 <i>R</i>	o	20 <i>r</i>
2372.197	1	1	4578.564	4	20
2398.565	o <i>r</i>		4581.405	5	30
2994.960	1	1	4585.876	7 <i>R</i>	
2997.338	2	3	4685.872	1 <i>R</i>	30
2999.650	1	2	4778.138	2 <i>R</i>	3
3000.871	1	1	5041.610	1	2
3006.875	o	2	5188.859	2	3
3009.194	1	1	5260.393	o <i>r</i>	o
3158.880	50 <i>r, R</i>	10	5261.708	3 <i>r</i>	3
3179.342	50 <i>r, R</i>	15	5262.254	3 <i>r</i>	3
3181.270	10 <i>R</i>	3	5264.247	3 <i>r</i>	3
3487.748	1	2	5265.563	3 <i>r</i>	3
3602.09 <i>br</i>	1		5270.276	3 <i>r</i>	3
3624.136	2	10	5349.450	4 <i>r</i>	4
3631.004	3	8	5512.987	4 <i>r</i>	4
3644.410	3 <i>r</i>	20	5581.978	4 <i>r</i>	4
3706.164	50 <i>R, r</i>	10	5588.780	6 <i>r</i>	6
3736.920	50 <i>R, r</i>	20	5590.225	3 <i>r</i>	3
K 3933.786	1000 <i>r</i>	500 <i>r</i>	5594.474	4 <i>r</i>	4
3948.902	o <i>r</i>	8	5598.598	4 <i>r</i>	4
3957.035	2 <i>r</i>	8	5601.287	3 <i>r</i>	13
H 3968.488	500 <i>r</i>	300 <i>r</i>	5602.765	3 <i>r</i>	3
3973.724	1 <i>V, r</i>	8	4557.456	8 <i>r</i>	8
4092.86 <i>br, n</i>	o	2	5967.560	2 <i>r</i>	2
5094.95 <i>br, n</i>	1	4	6102.824	9	9
4098.53 <i>br, n</i>	1	4	6122.218	10 <i>n</i>	10
4132.55	oo		6161.294	4	4
g 4226.751	100 <i>r</i>	1000 <i>r</i>	6162.176	15 <i>r</i>	15
4240.426	o	2	6163.757	3	3
4283.014	20 <i>r</i>	50	6166.538	4	5
4289.372	20 <i>r</i>	50	6169.036	6	6
4298.995	20 <i>r</i>	30	6169.565	6	7
4302.522	50 <i>r</i>	100	6439.084	8 <i>r</i>	8
G 4307.736	20 <i>r</i>	100	6449.820	6	6
4318.645	30 <i>r</i>	50	6455.213	1	2
4355.087 <i>br, n</i>	1	2	6402.577	5	5
4425.440	20 <i>dr</i>	V100	6471.665	4	5
4434.965	20 <i>dr</i>	100 <i>r</i>	6493.784	6	6
4435.687	15 <i>dr</i>	50	6499.662	4	4
4454.874	30 <i>r</i>	200 <i>r</i>	6572.714	1	1
4456.625	15 <i>r</i>	20	6717.721	5	5
4456.625	5 <i>r</i>	8			

CHROMIUM

2132.749	o		2144.300	o	
2133.568	o		2150.815	o	
2134.651	o		2170.777	o	
2135.490	o		2171.196	o	
2141.285	o		2183.799	o	

CHROMIUM—Continued

WAVE-LENGTH	INTENSITY		WAVE-LENGTH	INTENSITY	
	Spark	Arc		Spark	Arc
2185.098	o		2306.940	o	
2190.895	o		2370.278	I	
2191.710	o		2310.101	o	
2198.069	o		2314.729	I	
2198.698	o		2314.729	I	
2203.325	o		2314.820	I	
2208.788	o		2319.150	I	
2211.897	o		2319.489	I	
2213.883	o		2320.200	I	
2217.591	o		2324.985	2	
2218.752	o		2330.103	o	
2219.700	o		2333.551	I	
2226.781	o		2333.970	o	
2231.900	o		2334.330	o	
2233.873	o		2334.508	o	
2235.970	I		2334.618	o	
2237.651	I		2337.817	o	
2241.430	o		2340.551	o	
2241.902	o		2344.645	o	
2243.390	o		2345.407	o	
2243.740	o		2365.290	2	
2244.213	I		2366.891	I	I
2244.970	o		2381.586	I	I
2247.809	o		2389.859	I	I
2248.000	o		2394.100	I	
2248.408	o		2397.848	I	
2248.693	o		2397.848	I	
2249.950	o		2398.600	o	I
2250.098	o		2399.745	o	I
2251.617	o		2400.318	o	
2252.140	o		2404.054 <i>br</i>	o	
2256.149	o		2408.764	o	I
2256.860	o		2413.722	o	
2257.250	o		2416.471	I	
2257.002	o		2419.490	o	
2257.896	o		2419.986	o	
2258.147	I		2420.206	o	
2258.250	o		2425.292	o	
2258.750	o		2425.745	o	
2261.829	o		2428.448	o	
2265.020	o		2429.746	o	
2273.502	I		2430.204	o	
2275.601	o		2433.305	I	
2276.560	I		2435.392	o	
2277.578	o		2438.551	I	
2284.580	I		2445.178	o	
2287.300	o		2445.649	o	
2289.309	o		2446.148	o	
2290.755	I		2446.959	o	
2295.640	I		2449.701	I	
2297.270	I		2450.020	I	
2300.589	I		2450.443	o	

CHROMIUM—Continued

WAVE-LENGTH	INTENSITY		WAVE-LENGTH	INTENSITY	
	Spark	Arc		Spark	Arc
2452.794	o		2516.000	o	
2454.140	o		2516.717	I	2
2454.545	I		2518.410	2	2
2455.302 <i>br</i>	o		2519.646	o	2
2456.87 <i>br</i>	o		2520.744	I	
2458.902	o		2522.79	o	
2459.051	o		2523.402	3	
2460.542	o		2523.746	I	
2460.950	o		2527.195	o	2
2462.437	o		2527.516	o	
2465.024	o		2530.057	2	
2465.728	o		2530.304	I	I
2465.865	o		2531.097	I	
2466.334	o		2531.935	o	
2466.4 <i>br</i>	I		2534.410	I	I
2469.222	I		2536.900	o	
2469.605	o		2537.805	o	
2470.944	o		2538.419	4	
2472.955	I		2539.046	o	
2475.028	o		2542.880	o	
2475.770	o		2543.229	I	
2477.025	o		2544.410	o	
2477.852	o		2545.287	o	I
2479.908	I	I	2546.068	o	
2483.184	I		2246.547	o	
2483.903	2		2547.650 <i>br</i>	o	
2485.604	o		2548.146	I	
2486.413	I		2548.668	I	
2486.752	o		2550.127	o	
2487.176	o		2550.416	o	
2489.413	I		2551.697	2	
2489.870	o		2552.001	o	
2490.209	o		2555.647	2	
2490.87 <i>br</i>	o	I	2557.149	o	2
2492.747	I	2	2557.570	o	
2492.990	I	2	2558.500	o	
2493.387	I		2559.924	I	
2496.52 <i>br</i>	o	2	2560.814	o	2
2497.04 <i>br</i>	o		2561.134	o	
2497.983	o		2561.951	o	
2498.945	I	I	2562.603	o	
2501.602	o		2563.448	I	
2504.432	o	2	2563.696	2	
2505.937	o		2564.864	o	
2506.185	o		2566.447	o	
2506.49	o		2566.595	o	I
2510.346	o	I	2566.993	o	
2511.310	o		2567.470	o	
2512.109	o	I	2567.71 <i>br</i>	I	
2512.518	o		2568.704	I	I
2513.817	2	I	2569.572	o	
2515.201	2		2570.940	o	

CHROMIUM—Continued

Wave-Length	Intensity		Wave-Length	Intensity	
	Spark	Arc		Spark	Arc
2571.896	I	2	2632.693 <i>br</i>	0	
2572.239	0	I	2633.746 <i>br</i>	0	
2573.658	I	I	2634.447 <i>br</i>	0	
2574.285	0		2635.874 <i>br</i>	0	
2575.898	0		2636.447	0	
2578.398	I	2	2637.290	0	
2579.204	0	I	2637.601	0	
2582.029	0	I	2639.248 <i>br</i>	0	I
2582.350	0		2640.100 <i>br</i>	0	I
2583.734	0	I	2640.827	0	
2584.206	I		2641.518	0	
2585.027	0		2641.946	0	I
2585.720	0		2643.669	0	
2587.508	I	I	2647.612	0	
2588.106	0	I	2648.240	0	
2588.306	0	I	2650.947	0	
2589.150	0		2652.215 <i>br</i>	I	
2589.806	I		2663.606	3	3
2590.540	0	I	2655.897	0	
2590.865	2	3	2657.710 <i>br</i>	0	
2591.944	0		2658.695	2	3
2595.664	I		2659.047	I	3
2596.197	I	I	2659.586	0	
2601.978	0		2659.890	0	
2603.051 <i>br</i>	0	I	2660.896	0	
2603.816	0		2661.485	2	
2604.247	0		2661.850	2	I
2605.730	0		2663.147	0	
2606.169	0		2663.588	4	3
2606.640	I		2663.800	2	1
2607.729	0		2665.798 <i>br</i>	I	
2608.003	I		2666.195	6	3
2608.247	0	I	2668.076	I	
2608.906	0		2668.835	5	3
2610.194	0	I	2670.215	2	
2610.930 <i>br</i>	I		2670.406	I	
2611.103 <i>br</i>	0		2671.953	6	3
2611.697	0	I	2672.505	I	I
2612.48	0	I	2672.935	4	3
2613.307	0	I	2675.396	0	
2613.616	0		2675.791	2	
2614.715	I		2676.675	0	
2616.301	0		2677.270	2	4
2616.548	0		2678.874	8	3
2618.854	0	I	2680.005	0	
2619.729	I	I	2680.396	I	I
2620.626	I	I	2683.550	I	
2623.472	I	2	2684.227	0	
2626.146	I		2685.165	0	
2626.885	I	I	2685.252	0	
2628.006	I		2686.105	0	
2631.005	2		2686.490	0	

CHROMIUM—Continued

WAVE-LENGTH	INTENSITY		WAVE-LENGTH	INTENSITY	
	Spark	Arc		Spark	Arc
2687.174	5	3	2733.690	0	
2688.394	10	2	2734.859	0	
2689.278	2		2735.828	0	
2689.908	0		2737.140	0	I
2690.504	0	I	2739.499	I	2
2691.147	10	3	2739.841	0	
2692.235	2		2740.172	2	I
2693.615	5		2741.165	I	2
2694.800	0		2742.128	5	2
2696.853	I	I	2743.704	6	
2697.594	3		2744.367	I	
2698.015	4	I	2745.043	2	
2698.515	3	3	2745.486	0	
2698.734	2	3	2746.263	3	
2698.940	3	I	2747.950	0	
2699.496	0		2749.023	7	3
2700.710	0		2749.885	I	
2701.221	I		2750.817	10	3
2701.215	I		2751.965	10	I
2701.788	0		2752.490	0	
2702.115	0		2762.903	0	3
2702.670	0	I	2753.286	0	
2703.087	0		2753.753	0	
2703.645	5	I	2754.000	I	
2703.951	I	I	2754.396	2	
2704.883	0	I	2755.115	0	I
2705.549	0	I	2755.340	I	I
2706.227	0		2756.384	2	
2706.665	0	I	2757.036	I	4
2708.904	4		2757.805	7	3
2709.420	4		2758.723	0	
2711.015	4		2759.075	3	
2711.306	0		2759.496	3	I
2712.413	5	2	2759.825	2	
2715.750	0		2760.145	I	
2717.096	0		2760.406	I	
2717.587	2	I	2760.485	I	
2718.210	I		2760.612	I	
2718.485	6		2760.957	0	
2719.157	0		2761.845	0	3
2720.178	2		2762.701	10	3
2720.365	I		2762.846	I	I
2720.787	0		2763.695	I	
2722.825	4	2	2764.096	0	
2723.688	3		2764.395	I	
2724.121	3		2765.147	0	
2726.362	0		2765.583	I	
2726.583	0	5	2765.700	0	
2727.317	4	I	2766.005	I	
2728.250	0		2766.624	15	4
2729.829	0		2767.353	0	
2731.989	0	5	2767.692	0	I

CHROMIUM—Continued

WAVE-LENGTH	INTENSITY		WAVE-LENGTH	INTENSITY	
	Spark	Arc		Spark	Arc
2768.253	0		2826.198	0	
2768.682	3		2826.285	1	
2759.451	0		2826.550	0	I
2769.983	0	6	2828.078	0	
2771.405	0	I	2828.906	0	
2772.032	I		2830.635	20	I
2772.477	0		2832.592	3	
2773.425	2		2833.586	0	
2774.561	2		2834.397	3	
2776.754	I		2835.707	25	4
2778.175	3	I	2836.590	I	
2779.053	0		2838.000	I	
2780.415	4	8	2838.903	4	I
2781.027	I		2839.237	0	
2781.205	I	I	2840.137	7	I
2782.480	2		2840.566	0	
2782.697	0		2842.517	0	
2783.959	0		2842.895	0	I
2784.450	0		2843.350	15 r	4
2785.249	0		2846.497	2	
2785.820	7		2846.796	I	
2786.580	2		2848.500	I	
2787.715	3		2849.456	0	
2788.003	0	I	2849.936	10	4
2789.184	0		2850.447	0	
2789.507	3		2850.740	0	
2792.256	10		2851.485	6	I
2793.765	0		2852.390	0	
2795.643	I		2852.795	0	
2798.803	2	I	2853.346	2	
2800.290	I		2853.935	0	
2800.884	10	I	2854.271	0	
2803.447	0		2854.713	0	
2804.143	0		2855.141	I	
2808.137	I		2855.747	10	3
2809.42 br	0		2856.413	0	
2809.714	0		2856.856	2	I
2810.250 br	I		2857.495	2	I
2811.000	0		2858.065	I	
2811.179	I		2858.742	I	I
2811.568	0		2859.020	3	3
2812.120	10	I	2861.047	4	3
2813.642	0		2862.685	10	3
2814.353	0		2865.214	3	3
2816.917	2		2865.455	I	I
2817.665	0		2865.803	0	
2818.075	0		2866.025	I	
2818.183	7	I	2866.842	4	3
2822.178	4	I	2867.239	I	I
2822.527	10	2	2867.740	4	3
2824.687	0		2868.741	0	
2825.649	I		2870.540	4	2

CHROMIUM—Continued

WAVE-LENGTH	INTENSITY		WAVE-LENGTH	INTENSITY	
	Spark	Arc		Spark	Arc
2871.559	0		2911.275	0	2
2871.737	0	2	2911.813	2	
2873.602	2	2	2913.655	0	
2873.957	I	I	2913.837	0	I
2874.625	0		2915.345	I	
2875.135	I		2916.187	0	I
2876.054	4	2	2921.342	2	
2876.385	2	2	2921.933	2	I
2876.754	0		2922.608	0	
2878.057	2	2	2923.600	I	
2878.536	I	I	2923.851	2	
2879.307	0	2	2926.279	I	
2880.987	3	I	2927.203	4	
2882.010	3		2928.271	2	
2885.418	0		2928.455	2	I
2886.525	0		2929.548	I	
2887.105	0	2	2930.932	I	
2887.875	I		2932.800	I	
2888.389	2		2933.715	0	
2889.297	2		2934.055	I	I
2889.613	2		2934.380 <i>br</i>	I	
2889.955	I		2935.255	3	I
2891.238	3		2937.027	I	
2891.527	0	I	2939.550	I	
2891.985	I		2940.340	I	
2892.890	0		2941.065	0	
2893.075	I		2942.070	2	I
2893.269	0	2	2945.832	0	
2893.625	0		2946.900	2	I
2894.378	I	2	2947.573	0	
2894.945	0		2949.572	I	I
2895.134	0		2949.885	0	
2895.788	0		2950.201	0	
2896.520	4	I	2950.781	0	
2896.878	I	2	2951.519	0	
2897.357	0		2952.060	0	
2897.810	2		2952.539	0	
2898.649	4	I	2953.458	2	I
2899.253	I	I	2953.780	3	
2899.590	2		2954.741	0	
2901.147	0		2955.240	0	
2902.764	0		2956.705	0	
2903.010	0		2957.706	0	
2903.719	0		2959.671	0	
2904.088	I		2960.042	0	
2904.837	0	I	2961.832	3	I
2905.607	0	2	2963.570	0	
2906.275	0	0	2966.147	2	I
2908.417	0		2967.025	0	
2909.165	0	2	2967.730	0	3
2910.775	I		2968.805	0	I
2911.005	0	2	2969.770	0	

CHROMIUM—Continued

WAVE-LENGTH	INTENSITY		WAVE-LENGTH	INTENSITY	
	Spark	Arc		Spark	Arc
2971.230	o	3	3039.883	o	I
2972.040	IO	2	3040.350	o	
2975.587	o	3	3040.950	IO	3
2976.807	I		3041.910	4	
2979.858	IO	2	3042.945	o	
2980.915	o	3	3044.060	o	
2984.845	o		3044.385	o	
2985.485	IO	I	3047.790	o	o
2986.106 <i>br</i>	I	2	3047.915	o	
2986.579	I	3	3050.270	IO	o
2986.929	o		3050.830	o	
2988.159	I		3051.680	o	
2988.733	o	3	3052.331	o	o
2989.263	IO	I	3053.826	o	
2992.000	o	2	3053.988	I	5
2992.549	I		3055.526	o	
2992.645	o		3056.778 <i>br</i>	o	
2994.177	o	2	3057.956	o	
2994.840	I		3058.445	o	
2995.212	o	2	3059.640	I	o
2996.689	I	2	3061.772	o	o
2998.916	o	2	3063.460	o	
2999.426	o		3063.965	o	
3000.150	o		3065.201	o	I
3001.103	o	2	3067.291	I	
3004.045	I		3071.712	o	
3005.160	I	2	3072.570	o	
3010.735	o		3073.354	o	
3011.569	o		3073.784	o	I
3013.169	o	2	3077.370	I	
3013.840	I	3	3077.942	I	I
3014.900	o	3	3079.490	o	
3015.049	o	2	3083.790	o	
3015.300	o	2	3084.682	o	
3015.620	2		3085.521	o	
3017.691	I	2	3088.200	I	
3018.601	o	2	3093.615	2	
3018.910	o	2	3094.120	o	
3020.826	o	2	3095.085	o	
3021.876	I	3	3095.588	o	
3024.465	I	3	3096.209	2	I
3026.755	7		3098.228	o	
3028.180	2		3103.560	I	
3029.261	o	2	3107.658	2	
3030.356	I	2	3108.749	I	
3031.454	o	I	3109.439	o	I
3033.034	I		3111.010	o	I
3034.304	o	2	3112.030	o	
3034.634	o		3113.725	o	
3035.100	o		3115.265	I	
3037.160	o	2	3115.730	I	
3038.170	o		3116.811	I	

CHROMIUM—Continued

WAVE-LENGTH	INTENSITY		WAVE-LENGTH	INTENSITY	
	Spark	Arc		Spark	Arc
3117.351	0		3190.005	0	
3118.200	0		3194.112 <i>br</i>	0	
3118.764	10	3	3194.785	0	
3120.481	15	3	3197.225	15	3
3121.151	0		3198.153	0	0
3121.312	0		3200.025	0	
3121.945	0		3200.582	0	
3122.705	2		3201.435	1	
3125.109	20	3	3202.700	0	
3125.579	0	1	3203.646	0	
3128.819	4	2	3205.215	1	
3130.687	0		3208.106	0	
3132.169	20	4	3208.707	1	0
3134.420	2		3209.297	10	1
3135.429	2		3211.421	0	0
3135.852	2		3211.571	0	
3136.822	4	2	3212.560	0	
3137.252	0		3212.965	0	
3137.620	0		3216.610	2	
3138.321	0		3217.505	7	2
3140.041	0		3219.221	1	
3140.330	2		3219.711	0	0
3142.860	0		3219.901	0	
3143.050	0		3225.504	0	
3145.230	1		3229.324	0	0
3145.880	1		3229.560	0	
3147.350	4	2	3230.006	0	
3148.550	0	2	3231.759	0	
3149.935	1		3234.155	5	
3150.221	1		3237.840	0	1
3152.320	2	1	3238.205	0	0
3154.205	0		3238.635	5	
3155.245	0	2	3245.662	0	1
3158.145	1		3249.660	0	
3159.046	0	0	3250.761	0	
3159.225	0		3250.940	0	
3160.000	0	0	3251.719	0	0
3160.247	0		3252.002	0	1
3162.284	0		3252.615	0	
3163.796	0	1	3255.500	0	
3164.286	0		3257.944	0	1
3169.430	1		3258.905	1	
3172.260	2		3260.110	0	1
3173.630	0		3264.421	2	
3178.860	0		3266.440	0	0
3179.453 <i>br</i>	1	0	3268.651	0	
3180.821	10	2	3269.309	1	
3181.531	1	0	3269.950	1	
3183.428	3		3270.358	2	
3184.470	0		3271.260	0	
3186.880	0		3273.058	0	
3188.145	0	0	3274.141	0	

CHROMIUM—Continued

WAVE-LENGTH	INTENSITY		WAVE-LENGTH	INTENSITY	
	Spark	Arc		Spark	Arc
3276.069	0		3352.101	0	I
3278.931	0		3353.251	2	0
3279.675	0		3355.285	0	
3283.193	I		3357.542	3	
3286.010	I		3358.649	10	2
3286.460	0		3360.485	20	2
3288.160	0		3361.965	3	0
3291.408	0		3363.872	I	
3291.905	2		3364.851	0	
3295.110	0		3367.593	I	0
3295.623	4	0	3368.193	20	3
3298.482	0	0	3368.891	0	
3298.902	0		3369.202	I	
3301.384	0		3371.603	0	
3303.070	0		3372.270	0	
3304.914	0		3375.107	0	
3307.220	7	0	3376.428	0	0
3308.351	0		3376.830	0	
3310.028	0		3377.472	0	
3310.865	3		3378.476	4	0
3312.115	2		3379.514	2	0
3312.380	2		3380.961	4 R	2
3313.269	I		3382.825	10	2
3314.240	I		3385.493	0	0
3314.775	2		3386.661	0	0
3315.461	0		3387.852	0	
3316.658	0	0	3388.865	0	0
3322.869	0		3390.920	0	I
3323.710	0		3391.578	4	I
3324.231	2	0	3393.160	4	0
3324.491	3		3393.980	3	0
3326.571	0	0	3394.432	3	2
3328.525	2	0	3395.731	2	
3329.186	0	0	3399.655	I	
3329.620	0		3402.542	3	0
3333.070	0	0	3403.404	15	3
3335.530	6		3405.407 <i>br</i>	0	
3336.477	4	I	3408.911	20	3
3337.087	0		3410.715	0	0
3338.062 <i>br</i>	0		3411.164	0	
3339.932	10	2	3412.350	0	
3340.838	0		3415.588	0	
3342.110	0		3419.435	0	
3342.717	10	2	3421.353	10	3
3343.425	0	0	3421.770	0	
3344.654	0		3422.892	20	3
3346.154	0	I	3424.779	0	
3346.860	I	I	3426.252	0	
3347.970	5	I	3427.230	0	
3349.135	0	0	3427.745	0	
3349.519	I	0	3428.040	0	
3351.745	0	0	3430.012	0	

CHROMIUM—Continued

WAVE-LENGTH	INTENSITY		WAVE-LENGTH	INTENSITY	
	Spark	Arc		Spark	Arc
3430.565	o	.	3477.320	o	o
3431.415	o	o	3478.291	o	
3431.776	o		3478.889	o	o
3432.149	o	o	3480.439	o	
3432.480	o	o	3481.439	I	I
3433.453	4	I	3481.695	I	I
3433.715	I	3	3482.745	I	
3434.230	I	o	3483.650	o	
3435.819	o	o	3484.289	2	o
3435.962	o	o	3486.636	o	o
3436.332	I	2	3488.578	o	o
3436.878	o		3494.677	o	
3438.570	o		3495.108	o	o
3441.241	o	o	3495.530	2	o
3441.588	I	2	3495.679	I	
3443.939	o		3502.445	o	o
3444.501	o		3503.508	o	
3445.741	I	2	3508.236	o	
3447.149	o	o	3510.686	o	o
3447.567	o	I	3512.000	3	
3447.901	o	o	3513.217	o	
3449.400	o		3518.757		
3450.999	o		3522.262	o	
3453.469	I	2	3523.14	o	
3453.879	o	o	3527.201	o	o
3455.108	2	o	3513.572	o	
3455.336	o		3532.980	o	
3455.738	I	I	3536.615 <i>br</i>	o	
3457.78	4		3539.078	o	
3458.249	I	o	3547.180	o	
3459.428	2		3548.86 <i>br</i>	o	
3460.568	o	o	3550.431	I	I
3461.441	o		3552.76	I	
3462.869	o		3554.072	o	
3462.720	o		3556.218	o	
3464.151	o		3558.75 <i>br</i>	I	2
3464.978	o	o	3559.901	o	o
3465.390	o	o	3562.418	o	
3465.685	o	o	3562.56	o	
3466.40	o		3567.050	o	
3467.132	o	o	3564.410	o	
3467.845	o	o	3564.838	o	
3468.885	o	o	3566.454 <i>br</i>	I	3
3469.736	o	o	3569.238	o	
3470.585	o	o	3572.890	o	I
3471.650	o	o	3573.780	o	I
3472.216	2		3574.944	o	I
3472.948	o	o	3575.106	2	I
3473.036	o	o	3578.832	20 <i>r</i>	30 <i>r</i>
3473.760	o	o	3582.766	o	o
3474.525	o	o	3584.46 <i>br</i>	I	o
3475.270	2	o	3585.421	3	

CHROMIUM—Continued

Wave-Length	Intensity		Wave-Length	Intensity	
	Spark	Arc		Spark	Arc
3585.637	2		3686.926	I	I
3593.636	20 <i>r</i>	30 <i>r</i>	3687.454	2	I
3594.500	0		3687.690	2	I
3599.535	0	0	3688.572	I	0
3601.806	2	2	3689.414	0	0
3602.708	0	0	3689.667	0	
3603.919	10	I	3693.128	0	
3605.479	20	30 <i>r</i>	3696.807	2	
3608.547	0	0	3698.044	9	
3609.650	0	I	3711.496	I	
3610.218	0	I	3713.946	15	I
3612.789	0	0	3715.164	8	I
3613.109	2	0	3715.436	8	
3613.828	0	0	3716.481	I	I
3615.795	0	I	3723.373 <i>n</i>	3	
3617.450	0	I	3727.332 <i>n</i>	5	
3619.599	0		3730.314	2	2
3621.640	0		3732.064	3	2
3626.440	0		3737.590	3	
3631.758	9 <i>r</i>		3738.435 <i>n</i>	7	8
3632.979	I	2	3743.035	2	2
3634.097	0		3743.575	5	2
3634.996	0		3743.952	9	4
3636.728	2	3	3744.525	2	
3639.943	4	4	3747.326	2	
3641.597	0	I	3748.706 <i>br</i>	4	2
3641.970	2	2	3749.039	10	4
3643.305	0		3750.524 <i>br</i>	3	
3644.802	0		3754.652 <i>n</i>	8	
3646.0000	0	0	3757.238	I	I
3647.485	0		3757.739	6	4
3648.669	0	I	3758.107	3	2
3649.137	2	2	3761.748 <i>n</i>	2	
3649.920	0		3716.956 <i>n</i>	2	
3650.490	2	0	3767.487	I	I
3651.792	0		3768.296	6	5
3654.052	I	2	3768.799	3	2
3656.404	I	2	3778.600	2	
3658.316	0		3783.752	0	
3662.978	0	I	3788.917	I	
3663.346		I	3789.784	I	I
3664.755	I		3790.317	I	I
3666.110	0	0	3790.514	2	I
3666.781	0	I	3791.448	4	2
3668.155	0	0	3792.206	4	2
3676.457	0	0	3793.346	4	2
3677.815	I	0	3793.932	4	2
3677.965	3 <i>R</i>	0	3794.669	3	I
3679.170	0	0	3797.198	4	2
3681.838	0	0	3797.757	6	2
3684.370	I		3801.251 <i>n</i>	2	
3685.665	0	I	3804.878	10	6

CHROMIUM—Continued

WAVE-LENGTH	INTENSITY		WAVE-LENGTH	INTENSITY	
	Spark	Arc		Spark	Arc
3806.898	4	2	3894.022	10	2
3807.983	4	1	3897.657	9	0
3809.556	2		3902.107	0	0
3812.321	4	2	3902.947	2	2
3814.072 <i>n</i>	4		3903.188	0	1
3814.690	4	3	3905.668	0	
3815.500	5	2	3907.358	0	
3816.232	4		3907.787	0	0
3817.914	2	2	3908.765	0	4
3818.529	4	1	3911.392	0	
3819.645	6	1	3914.417 <i>br n</i>	0	0
3820.520	4	3	3915.469	0	1
3821.581	0		3916.040	0	1
3823.644	0	10 <i>r</i>	3916.268	0	2
3825.402	0		3917.180	0	0
3826.412	1	1	3917.589	8	0
3830.052	4	1	3919.167	3	7
3831.162	4	2	3919.968	4	0
3834.772	3		3921.046 <i>br n</i>	0	4
3836.102	6	1	3926.637	1	0
3841.282 <i>n</i>	1	2	3928.215	0	4
3849.012	1	1	3928.641	1	
3849.462	0	1	3936.128	1	
3849.631	1	1	3937.608	5	
3849.982	1		3938.397	1	
3852.202	10	2	3941.188	0	
3852.604 <i>n</i>	1		3941.495	0	3
3853.222	2	1	3943.518	1	
3854.262	1	1	3945.108	1	
3854.862 <i>n</i>	2		3945.491	1	0
3855.313	2	0	3945.959	12	0
3855.612	3		3948.858	3	0
3856.229 <i>n</i>	1	0	3949.66 <i>br n</i>	1	0
3857.659	1	1	3951.077	0	0
3862.583	8		3951.775	0	0
3865.662	1		3952.407	10	0
3866.575	1		3953.181	4	0
3868.299	8		3958.078 <i>br n</i>	1	
3870.291	0		3960.760	1	0
3871.462	1		3963.10	10	
3872.607	1		3969.145 <i>R V</i>	30	5
3874.588	1		3971.261	1	1
3875.257	8	15 <i>r</i>	3972.689	1	0
3789.186	1	1	3976.698	4	5
3881.318 <i>n</i>	9		3978.668	0	1
3881.811	0		3979.519 <i>n</i>	3	0
3883.327	0		3979.795	0	0
3883.635	1		3981.235	7	1
3885.221	10	3	3983.278	10	0
3886.799	1	3 <i>R</i>	3983.331	4	4
3890.867	1		3984.145	1	2
3891.927	4	0	3989.988	1	2

CHROMIUM—Continued

WAVE-LENGTH	INTENSITY		WAVE-LENGTH	INTENSITY	
	Spark	Arc		Spark	Arc
3991.192	0	4	4098.484	4	
3991.699	0	2	4099.122	2	0
3992.830	1	2	4099.450	1	
3993.851	0	1	4099.861	1	
3998.899	0		4101.162	2	
3999.677	2	0	4104.862	4	
4001.454	3	1	4106.423	2	
4002.549	4		4109.587	4	0
4003.339	4		4111.010 <i>br</i>	8	
4012.490	0	0	4113.259	2	
4014.689 <i>br n</i>	4	0	4120.640 <i>br</i>	3	0
4016.084	0		4123.327	4	
4018.269	1	0	4121.813	1	0
4022.250	2	1	4122.156	3	0
4025.025	0	0	4123.400	6	0
4025.368	0	1	4125.450	2	
4026.184	3	1	4126.521	8	0
4027.006	3	1	4126.918	2	2
4029.537	2		4127.058	2	0
4031.467	2	0	4127.274	4	0
4033.199	1	0	4127.588	4	0
4037.307	1	0	4128.506	4	0
4038.058	1		4131.355	6	0
4039.102	1	2	4132.398	1	
4042.601	0	0	4134.038	0	
4043.813	1	0	4142.178	4	
4048.767	4	2	4142.477	1	
4049.2 <i>n</i>	1		4145.798	10	
4049.766	1	0	4149.482	2	
4051.315	1	0	4151.118 <i>n</i>	3	
4052.462	2		4152.755	4	0
4054.377	0		4163.070	2	0
4056.077	0	0	4153.719	5	2
4056.812	0	0	4161.419	7	1
4058.774	2	2	4163.666	7	1
4060.615 <i>n</i>	1	0	4165.544	7	1
4064.738	0		4169.857	4	0
4065.720	1	1	4170.240	3	0
4067.530	0	1	4171.762	2	1
4068.493	3		4172.678	4	
4070.963	3		4174.821	4	2
4074.908 <i>n</i>	2	0	4175.344	3	0
4076.054	3	1	4175.958	3	0
4077.077	2	0	4177.838	2	
4080.413	0		4179.256	7	2
4081.723	0		4179.418	2	
4082.304 <i>br</i>	3		4184.969	1	1
4084.153	1		4186.347	2	0
4086.033	2		4190.038	1	1
4090.327	3		4191.284	3	2
4092.266	1		4191.781	3	
4093.073	1		4192.022	5	0

CHROMIUM—Continued

WAVE-LENGTH	INTENSITY		WAVE-LENGTH	INTENSITY	
	Spark	Arc		Spark	Arc
4193.687	2	I	4284.687	I	I
4194.857	I		4284.866	2	I
4195.331 <i>br</i>	2	2	4288.456	I	I
4197.241	3	2	4289.731 <i>R V</i>	30	30 <i>R</i>
4198.421	3	2	4291.984	2	2
4200.112	2	2	4293.560	2	2
4203.581	2	2	4295.960	4	3
4204.209	I	I	4297.048	3	2
4204.472	3	2	4297.754	3	3
4206.909	3	I	4299.756	2	2
4208.364	2	I	4299.966	I	I
4209.371	3	2	4300.516	2	2
4209.714	2	2	4301.171	2	I
4211.360	2	2	4302.791	I	
4212.649	2	2	4305.461	2	2
4213.170	2		4306.952 <i>br</i>	3	I
4216.366	2	2	4312.471	I	I
4217.567	0	2	4317.971	0	I
4221.584	3	2	4318.602	0	
4222.737	2	2	4319.640 <i>br</i>	3	2
4224.530	2	0	4320.681	I	I
4224.857	2		4321.312	I	I
4230.407	I	I	4321.681	I	I
4232.237	I	I	4323.572	2	2
4233.217	2	I	4325.132	5	3
4234.477	I	I	4337.563	II	10
4238.954	2	I	4338.408	2	I
4240.719	2	I	4338.808	2	I
4042.357	6	I	4339.448	8	5
4248.347	I	I	4339.713	7	4
4248.727	2	I	4340.128	3	2
4252.297	I	I	4341.091 <i>br</i>	2	I
4252.657 <i>n</i>	4		4343.203	I	2
4254.352 <i>R V</i>	30	50 <i>r</i>	4344.501	10	10
4255.506	2	I	4345.121	0 <i>r</i>	I
4256.157 <i>br n</i>	I	I	4346.818	2	3
4261.343	3	2	4351.047	6	8
4261.526	2	I	4351.761	10	15
4262.134	6	I	4353.861	2	I
4262.345	2	I	4356.761	2	I
4263.137	6	3	4357.532	2	I
4268.347	I	I	4359.515	6	8
4268.487	I	I	4363.098	4	3
4269.297 <i>n</i>	2		4368.231	2	I
4269.966	2	I	4369.861	0	
4271.086	2	2	4371.273	10	10
4273.987	2	2	4373.246	2	3
4274.805 <i>R V</i>	30	50 <i>R</i>	4373.641	2	I
4275.547	10		4374.162	6	3
4276.076	I	I	4375.324	3	3
4280.403	3	3	4376.773	3	2
4283.017 <i>br</i>	3		4377.546	3	2

CHROMIUM—Continued

WAVE-LENGTH	INTENSITY		WAVE-LENGTH	INTENSITY	
	Spark	Arc		Spark	Arc
4378.336	1		4511.911	2	3
4379.776	2	1	4514.510	0	2
4381.110	2	2	4515.338	0	1
4384.980	1 c	8	4521.152	0	1
4387.494	2	3	4524.848	0	1
4391.760	2	3	4526.115	0	1
4395.426	0	1	4526.480	6	8
4397.236	2	2	4527.462	2	4
4399.871	1	2	4529.852	0	2
4403.368	2		4530.698	1	
4403.497	3	3	4530.742	6	8
4410.299	2	2	4532.782	0	1
4411.076	2	2	4535.142	0	2
4412.251	2	2	4535.711	5	6
4413.837	3	2	4539.778	0	3
4422.286	2	2	4540.476	0	3
4423.266	2	1	4540.712	2	3
4424.293	3	3	4541.068	1	2
4425.156	2	1	4541.522	2	1
4428.557	2	1	4542.517	0	2
4429.966	2	1	4543.732	0	1
4430.486	2	1	4544.610	2	4
4432.166	3	2	4545.339	0	2
4433.875	1	1	4545.961	4	8
4442.266	2		4553.962 <i>n</i>	2	
4443.706	2	1	4554.972	0	
4458.426	5	3	4556.138	0	3
4459.351	2	1	4558.659 <i>V</i>	20	1
4462.776	2	1	4563.670	0	1
4464.756	2	1	4564.160	1	1
4464.806	2	1	4565.518	1	
4465.345	3	2	4565.778	1	4
4466.156	1	1	4569.618	1	3
4467.557	2	1	4571.679	2	4
4473.746	1	1	4575.110	1	2
4475.306	1	2	4578.210	1	1
4480.306	2 <i>r</i>	1	4580.058	2	8
4481.456	1		4584.100	1	1
4482.885	2	2	4585.13	1	1
4488.044	3	2	4586.220	1	1
4489.466	3	2	4588.240 <i>R</i>	15	1
4491.659	1		4591.400	4	8
4491.842	2	1	4592.060 <i>n</i>	4	
4492.311	4	1	4592.631	4	
4495.298	2	1	4595.580	1	2
4496.871	10	10	4598.430	1	1
4498.745	0	2	4500.109	1	2
4500.299	1	3	4600.762	4	6
4501.112	1	2	4601.037	1	2
4501.788	0	1	4601.500 <i>n</i>	2	
4506.868	0	2	4607.171 <i>n br</i>	2	
4510.048	1	1	4613.365	4	4

CHROMIUM—Continued

WAVE-LENGTH	INTENSITY		WAVE-LENGTH	INTENSITY	
	Spark	Arc		Spark	Arc
4613.921	2	2	4729.695	0	0
4616.126	5	4	4730.728	2	2
4616.531	1		4737.371	2	2
4618.841	6		4745.331	0	
4619.532	0	1	4752.101	2	1
4621.886	1	1	4756.131	4	4
4621.949	1	2	4764.299	1	1
4622.448	2 <i>r</i>	2 <i>r</i>	4766.647	0	0
4625.917	0	1	4767.869	0	0
4626.179	5	4	4789.348	3	3
4628.458 <i>br n</i>	5		4790.342	1	1
4632.141	6		4792.522	3	2
4633.093	6		4796.193	3	2
4637.173	1	1	4801.043 <i>n</i>	0	
4637.759	1	1	4803.430	0	
4639.500	0	1	4807.545	0	
4641.842	3		4812.380	0	
4643.142	3		4816.280	0	
4646.169	6	4	4824.140	6	
4646.498	2	1	4829.371	2	2
4646.784	0	0	4836.864	0	
4648.119	1	1	4849.665	4	
4649.853	0	1	4861.849	1	1
4649.435 <i>br</i>	3	2 <i>r</i>	4864.250	3	
4651.283	4	4	4870.816	3	2
4652.165	0	0	4876.340	3	
4654.122	6	4	4879.800	0	
4654.734	0	0	4884.640	0	0
4656.189	0	1	4885.875	1	1
4661.752 <i>n</i>	0		4885.952	0	0
4663.314	0	1	4887.203	3	2
4663.830	1	2	4888.528	0	0
4664.796	2	3	4901.532	0	0
4665.907	1 <i>r</i>	2 <i>r</i>	4903.262	0	0
4666.218	0	1	4906.774	3	2
4666.486	2	3	4922.281	0	0
4669.335	1	1	4936.347	1	2
4676.281	0	0	4942.495	0	1
4680.489 <i>n</i>	0	1 <i>r</i>	4954.828	1	1
4689.371	2	2	4995.787 <i>n</i>	0	
4693.956	1	1	5001.387 <i>br</i>	4	
4695.162	0	0	5004.384 <i>br</i>	4	
4697.061	1	1	5007.307 <i>br n</i>	1	
4698.529	4	4	5010.052	0	0
4699.640	0		5013.291	1	0
4700.526	1	1	5021.920	1	0
4705.451 <i>n</i>	0		5051.906	0	
4707.896	3	4	5065.900	0	
4708.027	4	4	5067.696	0	
4723.125	0	1	5068.307	0	
4724.413	0	1	5072.936	0	
4727.168	0	1	5090.974	0	

CHROMIUM—*Continued*

WAVE-LENGTH	INTENSITY		WAVE-LENGTH	INTENSITY	
	Spark	Arc		Spark	Arc
5110.782	o		5275.172	o	o
5113.142	o		5275.758	2	
5122.133	o		5276.069	o	o
5123.475	o		5296.711	4	1
5139.651	1	o	5298.294	6	1
5144.664	o	o	5300.768	o	o
5166.271	1	1	5328.144 <i>n</i>	3	o
5184.576	o		5345.816	6	1
5191.993	1		5348.336	5	1
5193.507	o		5400.624	o	o
5196.451	2		5409.793	5	1 <i>r</i>
5200.193	o		5664.004 <i>n</i>	o	
5204.518	6	6 <i>r</i>	5787.927	1	o
5206.053	6	6 <i>r</i>	5790.960	2	1
5208.434	6	6 <i>r</i>	6135.770	1	1
5225.032	1	o	6330.107	o	1
5237.331	o	o	6362.881	1	2
5247.675	2	o	6597.788	o	1
5255.133	o		6630.051	o	o
5264.167	5	1	6661.010	o	o
5265.725	1	o			

II. MEASUREMENTS OF ARC SPECTRA

INTRODUCTION

Measurements of the arc spectra of cerium and thorium have been made by Watts and by Hagenbach and Konen, but only over a limited range of the spectrum. Owing to the purity of some salts of these metals which were prepared by Dr. A. C. Neish of Columbia University and described by him in a paper entitled "A New Separation of Thorium from Cerium, Lanthanum and Didymium by Metanitrobenzoic Acid," it was thought advisable to measure the wave lengths over a more extended region of the spectrum.

APPARATUS

The same grating was used as that employed for the spark spectra. The dividing engine, to which reference has been made before, was constructed by Professor Rowland and was used in his work on the solar spectrum. For plates taken in the second spectrum of a 21-foot grating, the scale reads approximately to Ångström units.

The plates used were the same as those used in the work on spark spectra.

CORRECTIONS

In order to eliminate all lines due to impurities, the spectrum of the carbon arc was taken on each plate for comparison. They were also compared with the spectra of all elements likely to be associated with the substance under examination. This comparison was made by direct superposition of the plates. The lines, like those of spark spectra, were referred to the iron lines as determined by Fabry and Perot, and by Jewell, respectively. A calibration curve was also drawn for each plate as was done in case of the plates of spark spectra.

CERIUM

Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity
2651.125	o	3145.387	I	3233.555	o	3304.972	I
2652.572	o	3146.515	I	3234.301	3	3306.773	o
2660.406	o	3148.585	o	3235.032	1 r	3307.365	o
2831.047	o	3149.510	o	3235.801	o	3308.165	I
2854.755	o	3151.265	o	3236.859	2	3309.298	o
2854.087	o	3154.618	o	3242.275	o	3311.031	o
2874.256	o	3155.882	I	3243.499	2	3311.627	o
2908.525	o	3164.383	I	2345.301	o	3312.353	o
2956.047	o	3166.387	o	3245.671	o	3313.439	o
2964.921	o	3166.741	o	3246.812	I	3314.175	o
2972.812	o	3167.415	o	3249.292	o	3314.863	I
2974.700	o	3169.314	I	3249.555	o	3315.338	o
2977.024	o	3171.758	I	3252.640	I	3317.935	o
2977.565	o	3172.458	o	3254.178	I	3319.002	o
2991.003	o	3176.931	o	3256.802	o	3320.499	o
2995.703	o	3177.258	o	3259.013	o	3321.087	o
3002.247	o	3178.887	o	3259.965	o	3323.456	o
3002.863	o	3181.005	o	3261.115	o	3325.498	o
3003.655	o	3183.647	I	3263.543	o	3326.229	o
3008.079	I	3184.346	o	3264.033	o	3327.405	o
3037.849	o	3186.281	I	3265.594	o	3327.812	o
3052.073	o	3187.776	o	3270.276	o	3328.069	o
3055.345	I	3188.899	o	3271.288	o	3329.139	o
3056.857	I	3189.751	o	3271.672	o	3330.625	o
3063.115	2	3190.497	I	3272.135	o	3331.392	o
3068.778	o	3194.936	2	3272.389	2	3331.947	o
3069.776	o	3196.051	o	3272.847	o	3332.361	o
3071.238	o	3199.407	o	3275.001	I	3332.629	o
3071.735	o	3201.243	o	3276.351	o	3333.197	o
3073.025	o	3201.836	2	3279.135	o	3333.815	o
3077.470	o	3203.045	o	3279.981	I	3334.045	o
3079.752	o	3206.071	o	3280.647	o	3334.429	o
3080.049	o	3206.603	o	3281.221	o	3334.605	I
3083.789	o	3207.025	o	3283.491	o	3336.498	o
3084.568	o	3207.728	o	3283.840	o	3336.678	o
3090.503	o	3211.081	o	3284.356	o	3339.659	o
3091.431	o	3212.628	o	3285.349	I	3339.947	o
3096.641	o	3212.707	o	3286.163	o	3341.049	o
3097.041	o	3216.809	o	3286.501	o	3342.043	I
3103.501	I	3218.499	I	3287.537	o	3344.005	I
3107.578	o	3219.057	3	3288.287	o	3344.909	I
3109.069	o	3221.042	2	3288.885	o	3345.551	o
3110.403	o	3221.327	2	3290.503	o	3346.648	o
3111.318	o	3222.547	o	3290.729	o	3348.309	o
3127.612	o	3223.532	o	3293.751	o	3350.105	o
3130.441	o	3224.057	o	3295.078	o	3351.314	o
3130.981	I	3225.831	o	3295.440	I	3351.668	o
3132.725	o	3226.164	o	3296.337	o	3352.441	o
3133.461	o	3227.249	2	3297.040	o	3353.118	I
3136.842	o	3229.251	o	3298.475	o	3353.465	o
3137.731	o	3229.487	I	3300.141	o	3354.108	o
3142.399	o	3231.391	I	3300.289	o	3354.665	o
3144.708	o	3232.425	o	3303.365	o	3355.155	I

CERIUM—Continued

Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity
3356.549	I	3416.703	O	3469.152	O	3510.095	O
3357.347	I	3415.815	O	3469.543	O	3510.387	O
3358.589	O	3416.985	O	3470.289	O	3510.039	O
3359.491	O	3317.543	I	3470.562	O	3511.754	O
3359.602	O	3417.985	O	3472.167	O	3518.725	O
3360.703	2	3419.045	O	3474.372	O	3515.913	O
3361.946	I	3420.312	O	3474.938	O	3517.510	2
3364.185	O	3422.612	O	3475.799	O	3518.156	O
3364.493	O	3422.839	2	3476.483	O	3518.540	O
3364.978	O	3423.992	O	3476.985	I	3519.194	I
3365.997	O	3425.465	O	3477.554	O	3519.853	O
3366.708	I	3426.085	O	3478.111	O	3520.665	I
3368.544	O	3426.342	2	3479.147	O	3521.139	O
3368.872	O	3426.703	O	3479.752	O	3522.039	I
3368.938	O	3428.843	O	3480.463	O	3523.347	O
3369.352	O	3429.997	O	3480.519	O	3524.178	O
3371.352	O	3430.442	O	3481.165	O	3526.815	I
3371.352	I	3431.002	O	3481.320	O	3527.743	O
3373.047	I	3431.649	O	3482.265	O	3527.975	O
3373.910	I	3433.247	I	3482.531	I	3528.168	O
3374.315	O	3433.795	O	3484.892	O	3528.759	O
3375.272	O	3435.346	O	3485.197	2	3529.161	O
3375.939	O	3436.430	O	3486.978	O	3530.160	O
3377.274	I	3437.455	O	3488.665	O	3530.749	I
3379.321	O	3437.955	O	3490.287	O	3531.050	O
3381.658	O	3439.947	O	3491.805	O	3531.749	O
3383.558	O	3441.358	I	3492.647	O	3532.750	O
3383.849	I	3442.513	I	3493.250	O	3533.029	O
3384.102	O	3443.079	O	3493.859	O	3533.759	O
3385.493	O	3443.652	O	3494.798	O	3534.202	2
3387.922	O	3446.348	O	3495.157	O	3534.571	I
3389.802	O	3446.846	O	3495.613	O	3535.708	O
3390.671	O	3448.403	O	3496.075	O	3536.647	O
3391.758	I	3451.758	O	3496.478	O	3536.857	O
3393.746	O	3453.385	O	3497.491	O	3537.293	O
3394.071	O	3454.594	O	3498.759	O	3537.597	O
3394.283	O	3454.957	O	3496.635	O	3538.935	O
3395.187	O	3456.835	O	3500.157	O	3539.235	2
3395.187	O	3456.915	O	3500.832	O	3540.963	O
3395.565	O	3459.998	O	3501.604	I	3541.821	O
3396.882	O	3460.305	O	3501.729	I	3542.072	O
3398.853	O	3461.513	O	3501.957	O	3543.447	O
3399.115	O	3461.923	O	3502.803	O	3543.682	O
3400.405	O	3463.360	O	3503.057	O	3545.748	I
3403.749	O	3463.902	I	3503.195	O	3545.978	I
3404.268	O	3464.319	I	3506.399	O	3546.325	I
3405.047	O	3464.989	O	3506.895	O	3546.798	O
3405.951	O	3465.102	O	3507.485	O	3547.146	I
3406.102	I	3466.018	O	3508.108	I	3547.955	O
3406.347	I	3467.108	O	3508.615	O	3548.289	O
3408.549	O	3467.925	O	3508.848	O	3548.978	O
3412.450	O	3468.255	O	3509.397	O	3551.603	O
3415.751	O	3469.071	O	3509.888	I	3551.853	I

CERIUM—Continued

Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity
3552.249	0	3619.410	0	3667.759	0	3727.968	1
3552.872	1	3619.984	0	3667.964	2	3728.421	2
3554.780	0	3621.187	0	3668.705	0	3729.014	0
3555.949	0	3622.104	1	3671.931	0	3729.920	0
3556.497	0	3622.445	0	3672.161	0	3730.359	0
3557.351	0	3623.854	2	3672.790	1	3731.909	0
3558.865	0	3624.176	0	3673.650	1	3733.587	1
3559.473	0	3625.295	0	3674.091	0	3739.732	0
3561.002	3	3628.290	0	3676.127	0	3740.162	0
3561.704	0	3628.638	0	3679.124	0	3741.050	0
3562.238	0	3629.816	0	3679.411	0	3741.421	0
3563.945	0	3630.184	0	3679.911	0	3741.759	0
3566.204	0	3633.414	0	3680.454	0	3744.066	0
3568.247	0	3631.232	1	3680.141	0	3746.387	1
3568.487	0	3632.136	0	3680.860	0	3748.067	1
3569.448	0	3633.414	0	3681.397	0	3750.136	0
3569.975	0	3636.086	0	3682.100	0	3751.066	1
3571.132	0	3637.534	0	3687.810	0	3751.509	2
3572.548	0	3637.764	0	3688.665	0	3752.407	0
3573.846	0	3638.018	0	3689.174	0	3752.466	0
3576.349	1	3638.241	0	3693.457	0	3752.913	0
3577.579	2	3639.486	0	3693.716	0	3753.816	0
3580.725	0	3640.726	0	3694.918	1	3755.473	1
3580.941	0	3641.157	0	3695.957	0	3755.780	1
3583.775	0	3642.618	0	3696.097	1	3756.327	0
3584.497	0	3642.827	0	3697.693	0	3757.266	0
3586.927	0	3643.464	0	3698.128	0	3757.897	0
3587.383	0	3644.336	0	3698.368	0	3759.190	0
3587.779	1	3645.235	0	3698.650	0	3759.780	0
3588.270	0	3645.451	0	3699.928	0	3760.426	0
3588.593	1	3646.650	1	3702.818	0	3760.735	0
3590.778	1	3646.860	2	3705.016	1	3763.006	1
3593.329	0	3647.531	0	3706.859	0	3763.637	0
3594.219	0	3647.764	1	3702.408	0	3764.136	2
3596.257	0	3649.703	0	3702.648	0	3765.053	1
3596.878	0	3650.137	0	3709.962	3	3765.906	0
3597.392	0	3650.910	1	3710.714	0	3766.063	0
3598.347	1	3652.1	0	3713.995	0	3766.533	0
3600.137	0	3652.292	0	3714.801	0	3768.012	0
3600.742	2	3653.111	1	3715.148	0	3768.283	0
3601.826	0	3653.640	1	3715.469	0	3768.777	1
3604.216	1	3654.908	1	3716.369	2	3769.075	0
3606.167	0	3655.823	2	3716.919	0	3769.973	0
3607.659	1	3659.230	1	3717.498	0	3770.816	1
3607.887	0	3659.869	0	3718.195	1	3771.637	1
3609.735	2	3660.037	0	3718.371	2	3772.686	0
3610.947	1	3660.637	1	3722.119	0	3773.256	0
3611.386	1	3661.711	0	3722.310	0	3773.483	0
3611.759	0	3662.859	0	3722.757	0	3776.118	0
3612.438	0	3663.699	0	3723.657	0	3776.630	1
3613.746	1	3664.707	0	3724.647	0	3777.088	0
3615.574	0	3665.137	0	3725.676	1	3777.665	0
3616.241	0	3666.012	0	3726.969	1	3779.613	0

CERIUM—Continued

Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity
3781.120	0	3834.754	0	3803.782	0	3930.810	0
3781.643	2	3835.732	0	3804.325	0	3931.007	2
3782.527	2	3836.076	1	3805.144	2	3931.390	1
3783.026	0	3837.182	0	3805.460	0	3931.844	1
3783.523	1	3838.257	2	3806.832	2	3932.148	1
3786.628	3	3838.542	2	3807.419	0	3932.084	0
3787.161	0	3843.739	0	3808.392	2	3934.744	0
3787.527	0	3848.559	2	3808.692	0	3935.231	0
3788.166	0	3849.525	0	3808.969	1	3935.907	0
3788.467	0	3852.110	0	3809.500	0	3937.124	0
3788.763	2	3852.395	1	3900.198	0	3937.614	0
3790.857	0	3853.164	2	3901.310	0	3937.804	0
3791.700	0	3854.154	2	3901.644	0	3938.058	2
3792.319	1	3854.275	2	3903.350	1	3939.521	0
3792.592	0	3855.203	2	3903.932	0	3939.613	0
3793.610	0	3856.335	0	3904.199	0	3940.224	2
3793.851	0	3856.620	0	3904.361	1	3940.607	0
3794.700	0	3856.964	1	3904.601	0	3940.945	1
3795.266	1	3857.209	0	3905.306	0	3942.163	4
3796.170	0	3857.591	1	3906.952	1	3942.714	2
3796.670	0	3857.840	0	3907.341	1	3943.111	0
3797.920	0	3860.392	0	3907.414	1	3943.450	0
3799.071	0	3860.790	0	3908.106	0	3943.917	3
3800.237	1	3862.428	1	3908.400	1	3944.876	0
3801.554	4	3866.785	0	3908.516	1	3946.680	0
3802.777	0	3868.092	1	3909.024	0	3947.850	1
3803.080	2	3868.464	1	3909.307	1	3949.377	2
3807.674	0	3870.863	0	3909.759	0	3949.790	0
3808.10	2	3874.674	1	3909.841	0	3950.133	0
3809.199	1	3875.017	1	3910.706	0	3950.812	0
3809.401	0	3876.104	0	3911.314	0	3951.642	0
3810.910	0	3876.857	2	3912.206	0	3952.205	0
3812.211	1	3878.352	2	3912.462	2	3952.613	8
3814.844	0	3881.658	0	3914.004	0	3953.647	1
3815.777	1	3881.897	0	3914.962	0	3954.960	2
3817.425	1	3882.454	1	3915.534	1	3955.372	1
3818.679	0	3883.563	0	3916.157	2	3955.941	0
3819.009	0	3883.967	0	3916.668	0	3956.012	0
3820.862	1	3884.206	0	3916.912	0	3956.235	3
3821.252	1	3885.220	0	3917.255	1	3956.898	2
3821.711	1	3885.724	0	3917.639	0	3957.180	0
3823.905	1	3885.978	0	3918.278	3	3958.860	0
3824.407	0	3887.164	0	3919.812	2	3958.214	1
3825.215	0	3888.365	0	3921.714	2	3958.870	2
3827.155	0	3888.984	0	3923.146	2	3959.613	1
3829.346	1	3889.289	0	3924.664	1	3959.846	1
3829.662	1	3889.498	0	3924.805	0	3960.412	0
3829.985	1	3890.019	4	3927.008	0	3960.941	2
3831.078	1	3890.511	0	3927.405	0	3962.102	0
3832.258	0	3890.760	0	3927.580	0	3963.414	0
3832.720	0	3891.005	1	3928.743	0	3964.217	0
3834.204	1	3891.794	0	3929.130	0	3964.522	1
3834.515	1	3893.246	0	3929.997	0	3967.174	2

CERIUM—Continued

Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity
3967.266	I	4010.186	0	4061.418	0	4095.840	0
3967.517	0	4011.597	0	4061.306	0	4098.160	0
3970.074	0	4012.195	0	4061.245	I	4099.10	I
3970.462	0	4012.430	5	4062.957	2	4099.769	0
3970.662	0	4014.920	2	4063.959	0	4100.918	I
3971.784	I	4015.878	0	4064.818	0	4101.787	2
3972.108	I	4018.600	0	4065.176	0	4102.300	0
3973.188	0	4019.059	0	4066.548	0	4104.450	0
3974.000	0	4019.297	0	4066.918	0	4105.518	I
3974.247	0	4019.485	0	4067.200	I	4106.150	0
3975.098	0	4019.907	0	4068.487	I	4106.958	2
3976.738	0	4020.558	0	4068.858	2	4107.406	3
3977.529	0	4022.290	2	4070.127	0	4107.819	0
3977.797	0	4023.396	0	4070.866	0	4108.257	0
3978.668	2	4024.508	3	4071.128	0	4108.748	0
3979.950	0	4025.155	I	4072.956	I	4109.566	0
3980.038	I	4025.900	0	4073.500	2	4110.400	3
3981.917	0	4027.057	0	4073.850	I	4110.879	I
3982.218	0	4027.676	0	4074.667	0	4111.417	2
3982.920	2	4028.700	3	4075.728	2	4111.960	I
3983.100	I	4029.298	0	4075.908	3	4113.749	0
3984.677	2	4029.758	0	4076.286	I	4114.157	I
3986.158	0	4030.227	0	4076.879	0	4114.928	I
3986.417	0	4030.396	2	4077.465	I	4115.270	2
3989.447	I	4031.330	3	4078.337	I	4117.000	I
3990.128	I	4033.800	0	4078.557	3	4117.299	I
3990.450	0	4037.387	0	4079.038	0	4117.588	I
3990.718	0	4037.696	I	4079.319	0	4118.156	3
3991.238	0	4038.258	I	4079.705	I	4119.019	I
3992.157	0	4039.898	0	4080.456	2	4119.847	7
3992.297	3	4040.777	5	4080.560	2	4120.858	2
3992.906	I	4041.280	0	4081.258	3	4121.608	0
3993.188	0	4042.146	0	4083.260	2	4123.256	I
3993.957	2	4042.588	4	4083.535	0	4123.523	I
3994.605	0	4043.459	0	4083.659	0	4123.886	3
3995.450	0	4045.220	2	4085.270	2	4124.840	2
3996.488	0	4046.246	3	4086.418	I	4125.458	0
3997.485	0	4047.317	I	4087.359	I	4125.787	0
3997.747	0	4048.358	0	4087.590	0	4126.656	0
3999.278	5	4049.018	0	4088.589	0	4127.380	3
4000.749	0	4049.806	0	4088.876	I	4127.816	I
4001.087	0	4050.359	0	4088.967	0 R	4128.108	I
4001.575	2	4051.419	2	4089.788	0	4128.287	2
4001.776	I	4052.008	I	4089.846	0	4129.160	I
4002.858	0	4053.516	2	4090.520	I	4130.739	2
4002.987	0	4055.048	2 R	4090.968	I	4131.120	2
4003.198	0	4055.818	0	4091.879	0	4132.358	0
4003.789	3	4056.907	0	4092.120	0	4132.556	0
4004.606	0	4058.258	0	4092.749	0	4133.840	7
4005.655	2	4058.759	0	4093.327	0	4135.147	2
4007.598	I	4060.216	0	4094.000	I	4135.996	0
4008.677	0	4060.499	0	4095.165	0	4136.907	I
4009.096	0	4060.737	0	4095.467	0	4137.489	2

CERIUM—Continued

Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity
4137.668	3	4202.833	4	4288.646	1	4386.366	0
4138.107	I	4203.491	0	4289.915	3	4386.776	5
4138.370	I	4204.730	0	4292.615	I	4388.000	I
4139.459	0	4205.119	0	4292.796	0	4390.286	0
4139.836	0	4205.830	I	4294.797	I	4391.666	3
4140.518	0	4209.369	I	4296.075	I	4393.197	0
4140.797	I	4209.971	0	4296.366	0	4394.789	0
4142.430	2	4213.040	0	4296.726	7	4396.598	0
4142.846	I	4214.028	2	4299.364	2	4398.786	0
4144.520	2	4215.499	0	4300.345	3	4399.228	2
4145.018	3	4217.560	2	4304.296	0	4400.536	0
4146.250	2	4221.188	0	4304.746	0	4400.867	0
4148.160	0	4222.618	4	4305.147	0	4405.487	0
4148.907	0	4223.870	0	4306.738	3	4407.286	0
4149.056	10	4224.529	0	4309.736	2	4408.840	I
4150.976	2	4227.730	2	4310.748	0	4410.678	2
4152.076	3	4228.260	0	4311.647	0	4412.036	0
4153.165	I	4231.729	I	4315.395	I	4413.197	0
4154.457	I	4232.020	I	4317.316	0	4413.807	0
4155.266	0	4232.558	0	4320.736	2	4416.886	I
4155.555	I	4233.182	0	4324.817	0	4418.758	3
4159.048	2	4234.171	I	4326.837	0	4419.286	0
4160.166	I	4234.682	0	4330.405	I	4423.437	0
4161.187	I	4239.881	4	4331.786	0	4423.662	0
4162.671	0	4241.092	0	4332.700	I	4427.081	2
4163.548	I	4243.694	2	4334.871	0	4427.931	2
4165.229	3	4243.626	0	4336.342	2	4428.433	2
4166.677	I	4245.917	4	4337.792	3	4429.262	3
4166.906	2	4246.375	0	4339.336	2	4429.991	0
4167.802	I	4246.687	2	4340.577	0	4437.517	0
4169.816	4	4248.647	3	4342.188	0	4439.237	0
4172.145	0	4251.866	I	4342.487	0	4440.886	0
4174.287	0	4253.345	2	4343.597	0	4443.748	0
4175.245	0	4255.754	2	4345.936	2	4444.357	2
4176.056	0	4256.146	I	4346.436	0	4444.718	2
4176.715	I	4257.106	0	4349.788	3	4449.326	3
4179.297	I	4259.737	0	4352.637	2	4450.757	2
4181.116	I	4261.154	0	4353.408	I	4455.666	0
4185.345	2	4263.415	I	4359.086	0	4457.812	0
4186.578	10	4264.386	0	4360.186	0	4460.231	7
4187.287	2	4267.206	I	4360.478	0	4461.143	2
4189.166	0	4268.297	0	4361.677	0	4463.422	2
4189.607	I	4269.248	0	4364.666	3	4464.691	0
4190.635	I	4270.186	2	4366.098	0	4467.547	I
4193.084	3	4270.735	2	4367.577	0	4471.242	5
4193.256	2	4271.756	I	4368.236	0	4472.710	I
4193.855	I	4273.446	0	4369.249	0	4474.740	I
4194.897	I	4275.517	2	4372.428	0	4479.359	3
4196.216	2	4278.856	I	4373.836	2	4483.908	3
4197.616	3	4280.145	0	4375.936	2	4484.830	0
4197.974	I	4281.017	I	4380.087	0	4485.530	0
4198.643	10	4281.137	0	4381.799	0	4486.909	4
4201.242	2	4285.468	I	4382.157	3	4491.247	0

CERIUM—Continued

Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity
4495.398	o	4523.100	4	4551.338	1	4579.270	1
4496.247	o	4527.358	4	4558.620	o	4582.519	2
4497.850	1	4528.489	4	4560.320	3	4591.150	o
4500.368	o	4532.510	1	4560.908	2	4593.948	3
4506.448	o	4536.897	o	4562.368	7	4606.439	2
4508.109	o	4538.902	1	4565.279	o	4615.220	1
4509.198	1	4539.070	o	4565.867	2	4634.930	1
4511.660	o	4539.749	3	4572.298	4	4628.178	4
4515.870	o	4544.068	o	4572.730	o	4632.339	1
4518.029	o	4548.880	1	4578.790	1	4646.150	o
4519.598	o	4550.336	o				

THORIUM

3503.758	o	3532.031	o	3557.603	1	3600.558	o
3503.909	o	3534.663	o	3559.585	2	3600.975	o
3504.157	o	3536.115	o	3560.109	1	3601.206	2
3505.653	o	3537.245	1	3561.015	o	3603.372	2
3507.008	o	3537.568	o	3561.928	o	3603.518	1
3508.270	1	3538.349	o	3563.527	o	3603.765	o
3509.240 <i>br</i>	I	3538.507	o	3567.186	o	3604.208	o
3510.679	o	3538.903	o	3567.401	1	3604.846	o
3510.887	o	3539.425	2	3567.845	o	3605.802	o
3511.286	o	3539.711	3	3568.115	o	3607.536	o
3511.760	4	3540.475	o	3569.765	o	3608.530	o
3512.875	o	3541.753	o	3571.723	o	3609.362	o
3513.368	o			3572.531	3	3609.608	3
3513.805	1	3542.351	o	3573.382	1	3610.207	o
3514.656	1	3542.638	o	3573.669	o	3610.553	o
3515.006	o	3542.765	o	3575.443	2	3610.947	o
3515.847	o	3544.158	2	3576.559	o	3612.579	1
3516.403	o	3545.097	2	3576.682	o	3613.025	o
3516.689	o	3545.404	2	3579.460	1	3613.946	o
3516.947	o	3546.359	o	3580.371	o	3614.142	o
3518.535	o	4547.489	o	3582.148	1	3615.267	2
3519.008	o	3548.047	o	3584.286	o	3616.834	o
3519.805	1	3548.275	o	3587.115	1	3617.207	3
3520.814	o	3548.593	1	3588.375	o	3618.525	5
3521.200	o	3549.048	1	3589.253	o	3619.863	o
3521.386	1	3549.479	1	3589.465	1	3620.521	1
3522.058	1	3549.726	o	3589.865	o	3621.282	2
3523.656	o	3549.858	o	3591.203	o	3622.476	o
3525.758	o	3550.419	o	3591.578	o	3622.540	o
3526.148	o	3550.893	o	3592.937	1	3624.138	o
3526.760	1	3551.538	o	3593.992	o	3624.640	o
3526.858	1	3552.003	o	3594.247	o	3625.095	3 <i>R</i>
3527.445	o	3552.878	o	3595.448	o	3625.790	3
3528.967	1	3553.259	1	3595.752	o	3626.085	1
3529.065	1	3553.538	o	3597.629	o	3632.765	o
3530.435	o	3555.175	2	3598.247	1	3634.358	o
3531.590	o	3555.837	o	3599.476	o	3634.725	1
3531.754	1	3556.443	o	3599.885	o	3635.396	1

THORIUM—Continued

Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity
3636.080	I	3681.351	O	3724.875	O	3774.348	O
3637.701	O	3682.038	O	3725.553	O	3776.425	O
3638.457	O	3682.652	O	3726.890	2	3781.162	O
3638.779	O	3685.057	I	3727.306	O	3781.513	O
3639.896	2	3687.126	I	3727.428	O	3783.175	I
3641.241	O	3688.115	O	3728.049	I	3783.447	2
3642.375	3	3688.903	2	3730.048	I	3785.486	O
3643.641	O	3690.259	O	3730.532	I	3785.763	3
3644.473	O	3690.649	I	3730.905	O	3787.021	O
3647.484	O	3690.768	I	3731.565	O	3788.488	O
3647.786	I	3691.560	O	3734.728	O	3789.255	2
3648.287	O	3691.782	O	3737.645	O	3790.948	I
3648.535	O	3692.044	I	3738.847	I	3791.443	O
3649.378	2	3692.233	I	3741.001	O	3792.502	O
3649.865	I	3692.714	I	3741.343	4	3794.379	O
3650.945	I	3693.841	O	3742.407	I	3794.477	O
3651.705	O	3694.007	2	3743.054	2	3794.850	O
3652.317	2	3694.489	O	3743.641	O	3796.883	O
3652.684	I	3695.472	O	3744.870	O	3800.505	O
3653.701	I	3696.153	I	3745.753	O	3803.224	2
3654.613	O	3696.807	O	3746.105	2	3805.960	O
3655.248	O	3697.172	O	3747.693	2	3808.046	I
3656.350	O	3698.253	O	3750.648	O	3808.280	O
3656.890	O	3698.440	I	3751.247	I	3809.984	O
3658.206	2	3700.017	O	3752.728	4	3811.157	O
3658.326	2	3700.484	O	3753.387	O	3813.187	I
3658.941	O	3700.921	O	3754.182	O	3821.563	2
3659.654	2	3701.153	O	3754.740	I	3823.208	O
3659.773	2	3703.020	O	3755.336	O	3823.705	O
3661.750	I	3703.386	O	3756.007	O	3827.068	O
3663.352	I	3703.950	O	3756.438	O	3828.539	I
3663.847	2	3704.192	2	3757.829	2	3829.535	O
3665.821	O	3705.007	O	3758.612	O	3833.203	O
3667.134	O	3706.151	I	3758.888	O	3836.648	2
3668.272	I	3706.932	I	3759.443	O	3838.006	I
3670.152	2	3707.147	O	3759.551	I	3839.853	2
3670.735	O	3707.606	O	3760.448	O	3842.115	O
3671.684	O	3708.907	O	3761.235	O	3854.687	3
3672.448	O	3711.463	2	3761.647	O	3856.513	O
3672.663	O	3711.760	O	3762.473	I	3873.965	I
3673.447	2	3712.715	O	3763.035	3	3874.980	2
3673.949	I	3715.734	O	3763.439	O	3875.389	I
3674.203	I	3715.987	O	3764.450	O	3884.675	O
3675.049	O	3716.703	O	3765.354	O	3884.963	O
3675.287	O	3717.965	O	3666.241	I	3885.897	O
3675.692	2	3718.275	O	3768.035	I	3887.053	O
3676.818	O	3718.765	O	3768.565	O	3887.143	O
3677.850	O	3719.547	2	3769.750	O	3891.205	O
3678.163	2	3720.404	2	3770.208	I	3891.896	I
3678.591	O	3721.990	3	3771.514	2	3892.455	O
3679.275	O	3722.302	2	3772.358	O	3893.247	I
3679.348	2	3723.440	O	3772.803	O	3893.568	I
3680.623	I	3723.798	O	3773.901	2	3894.573	I

THORIUM—Continued

Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity
3895.054	0	3951.673	I	4025.752	0	4106.112	I
3895.549	I	3952.900	0	4026.259	0	4108.597	2
3898.614	0	3955.301	I	4027.138	0	4109.523	I
3900.268	0	3956.003	I	4028.785	0	4110.795	I
3900.716	0	3956.743	I	4029.086	I	4111.048	I
3901.027	I	3956.832	I	4030.137	0	4112.887	I
3901.289	0	3959.130	0	4030.985	0	4115.947	I
3901.811	0	3960.483	0	4032.085	I	4116.878	I
3903.252	0	3962.548	0	4032.263	I	4123.718	I
3904.236	I	3963.355	0	4034.407	0	4127.006	0
3905.237	I	3963.610	0	4035.042	0	4131.200	0
3906.948	0	3965.008	0	4036.175	I	4131.618	I
3911.136	0	3967.547	I	4036.702	I	4132.943	I
3912.090	0	3969.153	0	4040.021	0	4134.269	I
3912.438	0	3972.286	0	4041.359	0	4140.410	I
3913.157	0	3972.794	0	4043.276	0	4141.808	0
3913.965	0	3973.370	0	4043.573	0	4142.900	2
3915.365	0	3973.756	I	4051.048	0	4148.312	I
3916.534	0	3974.378	I	4053.705	0	4150.187	I
3916.879	0	3976.532	0	4059.403	0	4152.418	I
3917.385	0	3979.175	0	4060.038	0	4155.525	2
3918.186	0	3980.230	0	4063.547	I	4156.407	0
3918.402	0	3980.901	0	4064.475	0	4162.865	0
3918.621	0	3981.256	0	4065.789	I	4163.732	0
3919.143	0	3982.027	I	4067.601	I	4164.248	0
3922.350	I	3982.239	I	4069.364	2	4165.187	0
3922.756	I	3984.506	0	4069.610	I	4165.501	0
3923.930	0	3984.899	0	4071.925	0	4165.870	0
3925.247	0	3987.365	0	4072.785	0	4167.748	0
3925.338	I	3987.854	0	4075.683	0	4168.729	0
3926.838	0	3988.710	I	4075.887	0	4170.575	0
3927.308	0	3988.	I	4080.475	I	4171.463	0
3927.561	0	3990.646	0	4080.860	0	4171.803	0
3929.803	2	3991.903	0	4081.537	0	4178.087	2
3932.155	0	3992.447	0	4082.429	I	4179.721	I
3932.376	0	3994.701	2	4083.605	0	4180.011	0
3933.037	0	3996.212	I	4085.178	2	4181.015	0
3935.715	0	3998.015	I	4085.576	0	4193.078	0
3937.153	0	4000.453	0	4086.673	3	4202.005	I
3938.059	0	4001.237	0	4088.847	I	4209.003	3
3938.868	I	4001.864	0	4089.278	0	4216.065	0
3941.387	I	4003.246	0	4091.525	I	4217.247	0
3942.184	0	4003.458	I	4093.511	0	4218.234	0
3942.790	0	4005.202	0	4094.907	3	4218.572	0
3943.503	I	4005.679	0	4097.483	0	4220.101	0
3943.818	0	4006.515	0	4097.887	0	4224.208	0
3945.636	I	4007.163	I	4099.093	I	4224.565	0
3945.941	0	4008.331	I	4100.518	2	4229.472	0
3946.279	I	4009.175	I	4001.088	I	4230.441	0
3947.477	0	4011.891	I	4102.817	I	4233.357	0
3948.175	I	4012.620	2	4103.785 <i>br</i>	I	4234.358	0
3949.006	2 R	4019.271	4	4104.553	I	4235.046	0
3950.540	I	4022.233	0	4105.502	I	4235.337	0

THORIUM—Continued

Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity	Wave-Length	Inten- sity
4240.700	0	4298.896	I	4359.363	0	4436.016	0
4242.773	0	4299.850	0	4361.292	0	4436.239	0
4244.082	0	4300.801	0	4361.746	0	4436.420	0
4247.739	0	4306.389	0	4365.893	0	4439.148	I
4248.015	I	4307.188	0	4366.936	0	4440.548	0
4249.710	0	4309.976	3	4369.257	0	4440.856	I
4250.318	2	4313.000	0	4373.825	0	4443.075	0
4253.562	0	4313.307	I	4374.137	0	4447.790	I
4255.781	0	4315.336	0	4374.788	I	4454.507	0
4256.147	0	4318.346	2	4377.837	I	4458.031	0
4256.262	0	4319.109	0	4378.162	0	4461.162	0
4257.534	0	4320.146	2	4380.926	I	4465.352	2
4260.425	0	4320.595	I	4381.890	10	4469.511	0
4261.305	0	4327.146	I	4384.686	0	4472.301	0
4263.402	0	4328.697	0	4387.077	0	4474.090	0
4264.155	0	4329.519	0	4391.029	10	4480.829	0
4270.351	0	4331.979	0	4393.008	I	4481.642	0
4271.122	0	4333.965	0	4394.888	0	4485.783	I
4272.910	I	4334.727	2	4396.500	0	4486.101	0
4272.379	3	4337.386	2	4398.897	0	4486.892	0
4273.018	I	4338.120	0	4399.069	0	4487.487	I
4274.350	0	4341.036	0	4400.372	0	4488.648	2
4276.818	0	4342.285	0	4401.616	0	4492.225	0
4276.927	I	4342.434	I	4402.938	I	4493.336	I
4277.340	4	4343.612	0	4408.867	0	4496.307	0
4278.321	0	4343.991	I	4410.427	0	4498.934	0
4280.610	0	4344.333	I	4412.535	I	4499.966	0
4281.096	2	4344.661	2	4412.776	6	4505.198	0
4281.446	I	4346.450	0	4414.505	I	4510.527	2
4282.055	3	4347.742	0	4416.187	0	4512.477	0
4283.546	I	4349.883 <i>br</i>	I	4418.524	0	4513.676	0
4284.960	0	4353.299	0	4421.536	0	4524.848	0
4286.219	0	4354.481	0	4422.047	0	4531.609	0
4288.035	0	4355.300	I	4423.885	I	4532.288	0
4291.846	0	4357.585	0	4427.636	I	4533.307	I
4295.099	0	4358.310	I	4432.237	0	4534.118	0
4297.357	0	4358.559	0	4432.945	3	4535.236	0

III. EFFECT OF VARIATION OF CURRENT AND CAPACITY
UPON THE WAVE-LENGTHS OF SPARK SPECTRA

INTRODUCTION

Owing to the fact that the spark is always used for comparison in all line-of-sight work, it is of importance to know whether or not the wave-lengths of spark spectra remain constant under varying external conditions of current, capacity, etc. Although considerable experimenting has been done along this line during the last few years, yet there is a diversity of opinion among observers. As the spark

and arc lines did not coincide on several of the plates of spark spectra, this part of the investigation was undertaken to determine whether or not this displacement was due to mechanical causes.

HISTORICAL REVIEW

It has been observed by Hemsalech,¹ Schenck,² and others that when small amounts of self-induction were introduced into the circuit of a spark discharge, there was at once a complete extinction of all the air lines from the spark spectrum, and at the same time, a narrowing of all metallic lines. As the self-induction was increased, certain others, called "short lines," disappeared, while certain lines called "long lines," also present in the arc, remained visible or increased in intensity. There was also a third class which were absent in the ordinary condenser spark, being present in the arc, but which appeared on introducing self-induction in the circuit. But the function with which we are particularly concerned here is the effect of self-induction, capacity, and current, etc., upon the wave-lengths of the lines. Exner and Haschek,³ in the course of their measurements of the ultra-violet spark spectrum of the elements, observed that in many instances the wave-lengths of the lines in the spark spectrum differed considerably from the wave-lengths of the corresponding lines in the arc, this difference being often as much as 0.5 of an Ångström unit. They considered this difference as due to pressure in the spark, and with data taken from the tables of Humphreys and Mohler⁴ they estimated the pressure in the spark to be about 25 atmospheres.

Haschek and Mache⁵ then attempted to show the existence of such a pressure. A spark was produced in an air-tight vessel which was filled with air and connected to a manometer. On discharging the spark they observed a sudden rise of the manometer and interpreted it as due to a pressure in the spark; but the value thus obtained was much greater than that calculated from the difference between the wave-length of the arc and spark lines. They also found⁶ that

¹ *Comptes Rendus*, **129**, 285, 1899; *Journal de Physique* (3), **8**, 652, 1899.

² *Astrophysical Journal*, **14**, 116, 1901.

³ *Sitz. der Kais. Akad. der Wiss. in Wien*, 1897, and following years.

⁴ *Astrophysical Journal*, **3**, 114, 1896, and **4**, 175, 1897.

⁵ *Sitz. der Kais. Akad. der Wiss. in Wien*, 1898.

⁶ *Astrophysical Journal*, **19**, 351, 1899.

this effect increased to a maximum and then decreased as they increased the amount of capacity across the discharge circuit.

Eder and Valenta,¹ however, found no displacement whatever, in case of the lines studied by Exner and Haschek.

Kent² repeated some of Exner and Haschek's work and observed that in case of titanium the arc and spark lines did not coincide, due to capacity, but that the displacement did not amount to more than 0.04 of an Ångström unit for lines in which Exner and Haschek observed as much as 0.13 of an Ångström unit.

Middlekauff,³ working in this laboratory with the 21-foot grating, observed no shift in case of the spark lines of iron.

Keller,⁴ working at Bonn, observed a shift but found that it was due to the manner in which the light was allowed to fall upon the slit.

THE PRESENT INVESTIGATION: APPARATUS

The same grating was employed as that used for photographing the arc and spark spectra of the elements.

For electrodes, rods of Norway iron, and also metallic chromium, manganese, and calcium were used. These were turned down to the form of a blunt lead-pencil as stated before.

METHOD OF EXPOSURE

One of the greatest difficulties encountered was the mechanical shift which appeared in a greater or less degree upon nearly every plate. At first this was taken to be a true shift. In order to avoid any possibility of a shift due to a jar of the camera when the shutter was turned, the shutter was detached entirely and held in place by two iron clamps which rested on the floor.

The middle of the plate was generally used for photographing the spark, then the shutter was turned and the arc spectrum obtained on either side, thus making it possible to observe any shift that might occur. Plates were also taken in which the arc spectrum was on the center of the plate.

RESULTS

A large number of plates were taken by the method described above, and invariably it was found that no shift whatever occurred.

¹ Kayser, *Handbuch der Spectroscopie*, Vol. II, p. 308.

² *Astrophysical Journal*, **14**, 201, 1900.

³ *Ibid.*, **21**, 1116, 1895.

⁴ *Zeitschrift für Wiss. Phot.*, **4**, 209-231, 1906.

However, in the case of a few lines which were reversed either in the arc or spark, there was an apparent shift due to an unsymmetrical reversal. This is illustrated by the following wave-lengths of some of the chromium lines taken from the plates. In case of the fourth and fifth lines there was an unsymmetrical reversal of the arc lines.

λ Spark	λ Arc	
3823.644	3823.644 (<i>r</i>)	0.000
3875.257	3875.257 (<i>r</i>)	.000
4254.352	4254.354	.002
4645.853	4645.875	.024
4680.489	4680.505	.016

The effect of increasing the current in the primary of the induction coil was greatly to increase the intensity of the spark, but at the same time, to cause more lines to reverse. The latter was especially true in the case of calcium and manganese.

The current was varied from twelve to forty amperes, this being the limit of the coil. When forty amperes current was used, almost every line in the spark spectrum of both calcium and manganese was reversed, while many were doubly reversed and a few of the manganese lines were reversed three times.

Hence the conclusions to be drawn from the present investigation are the following:

1. In the case of a spark discharge in air, there is no change produced in the wave-length by variations in the circuit conditions up to 60 amperes except that due to unsymmetrical reversal of the lines.
2. There is no appreciable difference in wave-length between the arc and spark lines.

In conclusion, the author takes pleasure in acknowledging his great indebtedness to Professor Ames, at whose suggestion the work was undertaken, and under whose immediate supervision it was carried out. He also wishes to thank both Mr. L. E. Jewell for his interest and valuable suggestions during the progress of the work and Dr. A. C. Neish of Columbia University, who prepared and furnished the salts of cerium and thorium.

JOHNS HOPKINS UNIVERSITY
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BIOGRAPHY

Frank Lawrence Cooper was born at Owosso, Michigan, April 26, 1875. After receiving his early education in the district school and the Owosso High School, he taught for one year in a district school and then entered the University of Michigan in October 1896. While there he pursued a scientific course and graduated with the degree of B.S. in June 1900. The following three years he was engaged in teaching, the first year in the Manistee, Michigan, High School, and the next two years in the East Side High School at Aurora, Illinois.

The year 1903-1904 he spent in graduate work at the University of Michigan, receiving the degree of A.M. in June 1904; during this year he was also assistant in physics in the university. In the fall of 1904 he entered the graduate department of the Johns Hopkins University, and pursued advanced work in Physics, Physical Chemistry, and Mathematics. While here he has held a Hopkins Scholarship in Physics and has also been Research Assistant in Physics.

